Backyard Astronomy

You can learn many of the same things classical astronomers did by simply watching the night sky. But there is a bonus as well. Backyard astronomy is just plain fun, as evidenced by the many thousands of amateur astronomers who in their spare time pursue activities ranging from simply stargazing to searching for new comets.

This section is intended to give you some hints on how to become a backyard astronomer, beginning with learning the constellations and some of the stories associated with them. We will then briefly discuss small telescopes and star charts, introducing some of the terms used to describe the location of the planets. We will conclude with a description of some of the physical changes in your eye when you are observing in very dim light.

Learning the Constellations

One of the best ways to get started as a backyard astronomer is to learn the constellations. All it takes is a star chart, a dim flashlight, and a place that is dark and has an unobstructed view of the night sky. The star chart will generally tell you how to hold it so that it matches the sky for the date and time that you are observing.

Start by determining which way is north, using a compass if necessary. Then try to locate a few of the brighter stars, matching them up with the chart. This will give you some sense of how big a piece of the sky the chart corresponds to. Next, try to identify a few of the constellations. Focus at first on just a few of the brighter ones. For example, if you live at midlatitude in the Northern Hemisphere, the Big Dipper—part of the constellation Ursa Major—is a good group to start with because it is always in the northern part of the sky.

As you attempt to find and identify stars, your spread hand held at arm's length makes a useful scale. For most people, a fully spread hand at arm's length covers about 20° of sky, or about the length of the Big Dipper from tip of handle to bowl, as shown in figure E1.1. For smaller distances, you can use finger widths (a few degrees).

This scaling of sky distances with your hand makes it easy to point out stars to other people. For example, you can say that a star is two hands away from the Moon and at the 4 o'clock position, as illustrated in figure E1.2.

Once you have come to recognize a few of the constellations, you may be interested in the stories associated with them, that is, star lore.

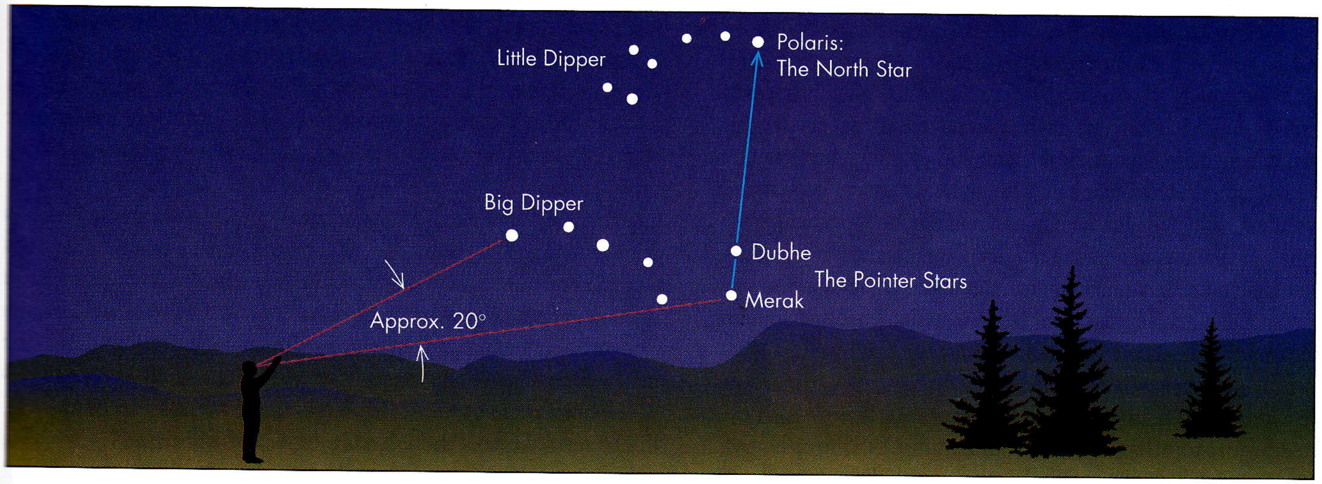

FIGURE E1.1
The Big Dipper, part of the constellation Ursa Major, the Great Bear. A line through the two pointer stars points toward Polaris. The Big Dipper spans about 20° on the sky, about a hand width at arm's length for most people.

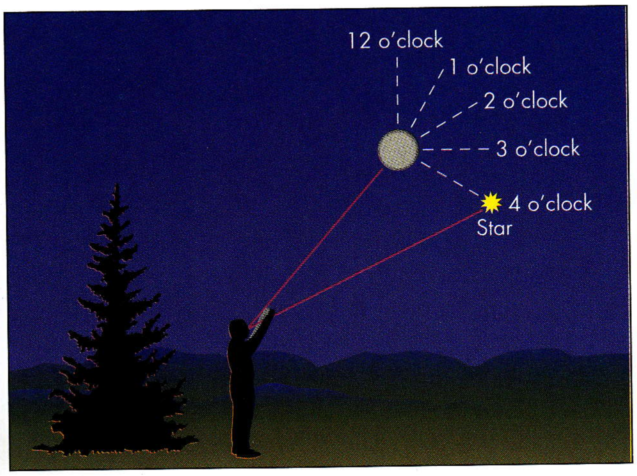

FIGURE E1.2
Describing the location of stars by clock position. The star is two hands from the Moon and at 4 o'clock position.

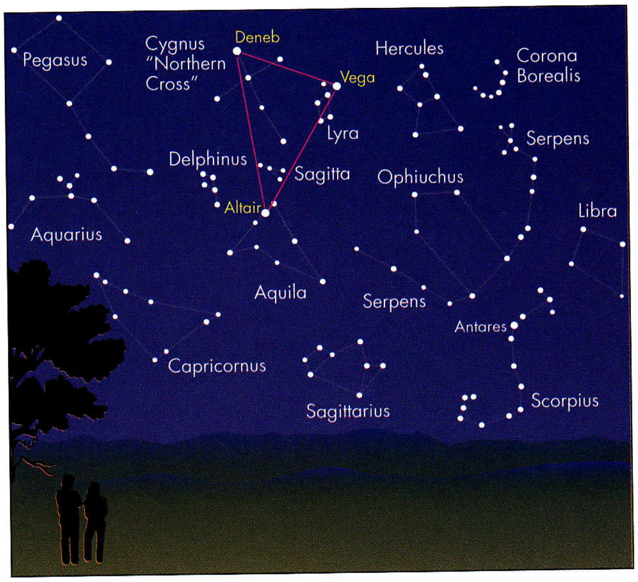

FIGURE E1.3
Dominating the night sky in July, August, and September are the three bright stars Vega, Altair, and Deneb, which form the summer triangle.

Star Lore

Star lore is part of virtually all cultures. The ancient Greeks, the Pawnee tribes of the American Midwest, the Australian aborigines, for example, all created stories about the star groupings they saw in the sky.

Because the star groupings do not change except on time scales of tens of thousands of years, the night sky we see is essentially the same night sky that ancient peoples saw. Star lore can therefore link us to the remote past. Furthermore, star lore can help us to remember constellations. In fact, it has been suggested that many of the stories were created as aids to memory, especially important in a time when familiarity with the stars could be literally a matter of life or death to a farmer or a navigator. Scientists have shown that baby birds learn to recognize star patterns and movements and use them to navigate safely—unguided by their parents—across thousands of miles of ocean to their winter homes. Perhaps we too have such instinctive faculties that help us learn the stars.

Probably the most familiar star grouping is the Big Dipper. It is not a constellation but rather is called an **asterism.** An asterism is an easily recognized grouping of stars that may be part of one constellation or may incorporate pieces of several. For example, the Big Dipper is part of the constellation Ursa Major, the Great Bear. The asterism of the Summer Triangle, on the other hand, spans three constellations. It consists of the three bright stars conspicuous in the summer evening: Deneb (in Cygnus, the Swan), Altair (in Aquila, the Eagle), and Vega (in Lyra, the Harp), shown in figure E1.3.

The Big Dipper is not only easy to spot, but it is also an excellent signpost to other asterisms and stars. For example, two of the stars in its "bowl" (see fig. E1.1) are called the "pointers" because they point, roughly, to the North Star, Polaris.

Polaris lies almost exactly above the Earth's North Pole, and because of its position there, it is the only star in the northern sky that shows, to the naked eye, no obvious motion during the night. Its relatively fixed position is illustrated by the time exposure in figure E1.4, showing the other stars rotating around it. Because Polaris always lies nearly true north, it is useful in orienting yourself to compass directions.

Polaris marks the end of the handle of the Little Dipper, another asterism and part of the constellation Ursa Minor, the Little Bear. The Little Dipper is not easy to see because its stars are dim, but it curves back toward the Big Dipper so that these two star groupings fill most of the sky directly around the north celestial pole.

The native inhabitants of North America had a story about the Big Dipper. Its bowl represented a huge bear, and the handle represented three warriors in pursuit of the bear. They had wounded it, and it was bleeding. The red color of the leaves in autumn was said to be caused by the bear's blood dripping on them when the constellation lies low in the sky during the evening hours of the autumn months.

If you follow the pointer stars in the Big Dipper past the Little Dipper and Polaris, you will come to a set of constellations tied together by an ancient Greek myth, the story of Perseus and Andromeda. The cast includes a king (Cepheus), a queen (Cassiopeia), the hero (Perseus), the princess (Andromeda), a sea monster (Cetus), and the winged horse (Pegasus). The constellations are shown in figure E1.5, and their story goes as follows:

In ancient days there lived a queen of Ethiopia, Cassiopeia, who was very beautiful but also very vain. She and king Cepheus, her husband, and their daughter, Andromeda, lived happily until one day the queen boasted that she was more beautiful than the daughters of Nereus, a sea god. In punishment for such pride, the sea-god Neptune sent a sea monster,

FIGURE E1.4
A time exposure showing how Polaris remains essentially fixed while the sky pivots around it. (Hermann Eisenbeiss/Photo Researchers, Inc.)

Cetus, to ravage the kingdom. To save his people and appease the gods, Cepheus was instructed to tie his daughter, Andromeda, to a rock for the monster to devour. Meanwhile, Perseus was returning home from a quest in which he slew the snake-haired Gorgon, Medusa. On her death, her blood dripped into the sea and turned into the flying winged horse, Pegasus. Medieval versions of the story have Perseus riding Pegasus, but the classical myth has him borne on winged sandals. Regardless of his means of travel, Perseus saw the maiden's peril and landed, slaying the monster and delivering the kingdom. They all lived as happily ever after as most mythological families, and their astronomical tableau is most easily seen in the late autumn, when the brighter of its constellations are high in the sky.

Stories are also told about stars in other parts of the sky. For example, in the winter sky, you can see the sad legend of the Hunter, Orion, and the maiden who refused to fall in love with him. The story also involves Orion's hunting dogs (Canis Major and Canis Minor), a bull (Taurus), a rabbit (Lepus), the maiden's sisters (the Pleiades—a cluster of stars in the constellation Taurus), and a scorpion (Scorpius).

The king of the island Chios had a lovely daughter, Merope. His island was filled with savage beasts, and to rid his kingdom of these dangerous animals, the king called upon Orion to kill the beasts and make his kingdom safe. When the task was done, Orion met Merope and made unwelcome advances. In punishment, he was blinded by the king, but after doing penance, he had his sight restored. After reaching an old age, however, Orion one day stepped on a scorpion, which stung and killed him. On his death, the gods placed him in the sky with his faithful dogs (one of whom chases Lepus, the rabbit), forever attacking the wild bull, Taurus. Beyond the bull, Merope and her sisters (the Pleiades) run from the hunter, who pursues them each night across the sky. The scorpion was also placed in the sky, but on the other side of the heavens so that Orion would never again be threatened by it (Orion is visible in the evening only in the winter, whereas Scorpius is visible in the evening only in the summer).

The Orion myth has several versions, but the one described here fits together many of the astronomical references. Another myth with several versions involves the late summer constellations Boötes and Virgo. They are linked by the gloomy story of Icarius, the first cultivator of grapes for wine. According to legend, his recompense for sharing this knowledge was to be killed by drunken peasants, who buried his body under a tree. His dog, Maera, led Erigone, his daughter, to the spot, where, on discovering her father's body, she killed herself out of grief. Icarius was placed in the sky as Boötes, and Erigone as Virgo. The dog Maera became the star Procyon.

There are many other stories about constellations, but the above may give you some sense of the ones that have been handed down for thousands of years of written and oral history. Pass them on.

Amateur Astronomy

Anyone with access to even very modest equipment such as binoculars or low-powered telescopes has better equipment than Galileo ever had. With such equipment and access to a

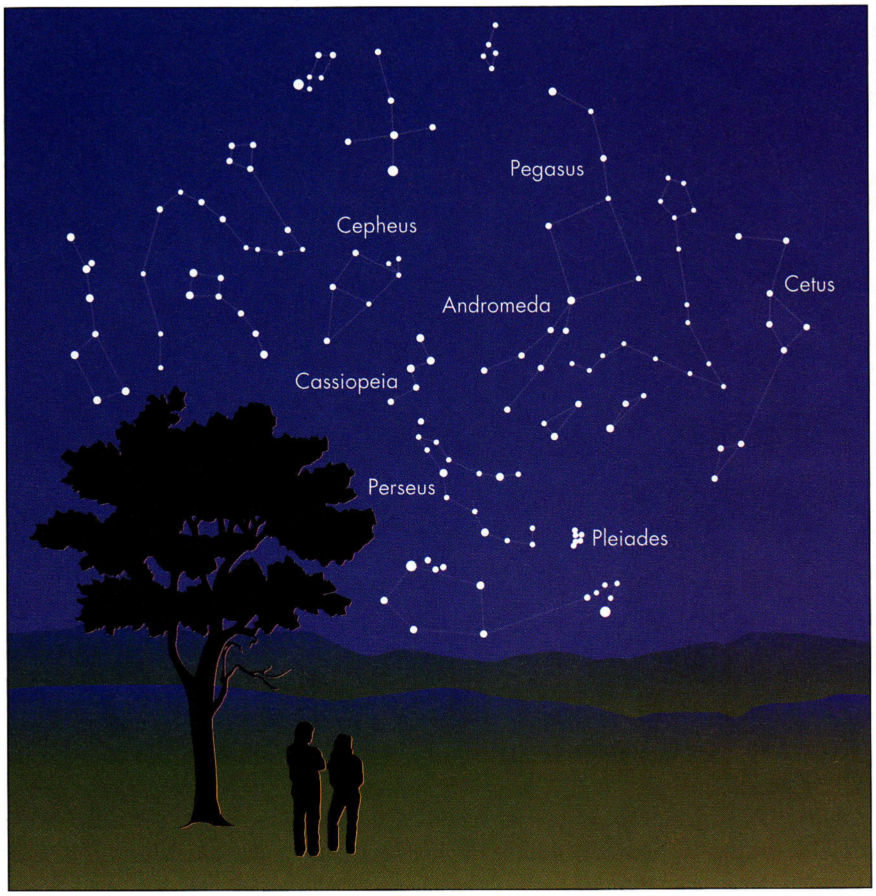

FIGURE E1.5
Perseus, Andromeda, Cassiopeia, Cepheus, Cetus, and Pegasus.
Can you spot the Big Dipper?

dark sky, that person can become an amateur astronomer. The pleasures of the hobby can range from the aesthetic satisfaction of taking a lovely photograph (fig. E1.6) to the thrill of discovering a new comet or an exploding star.

Many amateur astronomers now use digital cameras for astrophotography. These special digital cameras—similar to but far more sensitive than ordinary digital cameras—are still very expensive, but the results can be extremely impressive. With such a camera, you can take pictures with a backyard telescope that rival those made 40 years ago with a 200-inch telescope. However, you can also take surprisingly fine photographs with a simple 35-millimeter camera mounted on a tripod. Set the focus for infinity, open the diaphragm (f stop) all the way, and expose for 10 or so seconds with one of the high-speed color films (technically, ISO [ASA] 400 or higher). For many cameras, you can easily do this by putting the camera on the B (for "flashbulb") setting and holding the shutter release down for the desired time. A cable release will help you expose without shaking the camera but is not essential.

If you expose for more than about 15 seconds, the Earth's rotation will smear the star image into a streak. Deliberately allowing the smearing to occur can produce dramatic pictures of what are called "star trails" (see fig. E1.4). To make star-trail pictures, leave the shutter open for 20 minutes or so.

To take untrailed long exposures or to use a telephoto lens, you will need a way to compensate for the Earth's rotation. You can make a simple device to do this from hinged boards with a carriage bolt through them. Mount the camera on one board and set the other on a firm surface. Slowly turning the bolt will shift the camera, allowing you to take exposures of half an hour or so. For best results, however, you need a motor drive. Check your local library or the references at the end of the chapter for books or articles on drives and astrophotography. You may also find in such sources suggestions for scientifically useful projects, such as variable star observing or comet hunting. Projects like these are ideal for amateur astronomers because the results are not only valuable but also require basically only patience and care without the need for a big telescope.

Small Telescopes

A small telescope will greatly increase the number and interest of objects you can observe. Such telescopes come in a wide range of styles and prices, but selecting the best one for your needs can be confusing. Moreover, it is a sad truth that you

FIGURE E1.6
Picture of the Orion Nebula taken with a small backyard telescope.
(Courtesy of Carol B. Ivers and Gary Oleski.)

generally get what you pay for. Many amateur astronomers begin with a 3- to 4-inch reflecting telescope. Such a telescope uses a mirror to collect and focus the light; thus, its name, "reflecting." The numbers refer to the diameter of the mirror, important because a larger mirror collects more light, allowing you to see fainter objects. A larger mirror also permits seeing finer details with other things being equal (see chapter 4 for how a telescope works). With such a telescope, you can easily see the moons of Jupiter, the rings of Saturn, and many lovely star clusters and galaxies. However, these later objects will not look like the pictures in books because your eyes—unlike a photograph or electronic detector—cannot store up light.

Notice in the above we have said nothing of magnifying power. For most amateur telescopes, the maximum useful power is limited by distortions to the light as it passes through our atmosphere. These distortions make a magnification of about 100 to 200 the useful limit. Beyond that, the distortions dominate and higher power gives no increase in clarity.

Whatever type of telescope you choose, be sure to get a sturdy mounting for it. Even at 100 power, tiny vibrations of the telescope caused by wind or the touch of your hand will make the image jiggle, hopelessly blurring it.

Before you actually buy a telescope, you might want to talk with your instructor or a local amateur astronomer. Such people often belong to an astronomy club, some of whose members may have second-hand telescopes they are willing to sell at reduced prices. For information about new telescopes, browse through the magazines *Astronomy* or *Sky and Telescope*—publications widely read by both amateur and professional astronomers—which contain many advertisements for small telescopes.

Star Charts

One of the pleasures of using a telescope is to look at objects too faint to be seen by the naked eye, such as most galaxies, faint star clusters, and remnants of dying stars. To find many of these dim objects you will need a good star chart.

Astronomers use star charts to find objects in the sky much as navigators use charts to find places on Earth. A typical star chart (fig. E1.7) shows the location of the constellations, the stars, and other objects. It also gives some indication of the relative brightness of the stars. Finally, many charts also have information about the season and time of night at which the stars are visible.

Star charts are designed much like maps of the Earth. For example, both represent on a flat surface a map of something curved—in one case the celestial sphere; in the other the surface of the Earth. Also, both use a coordinate grid.

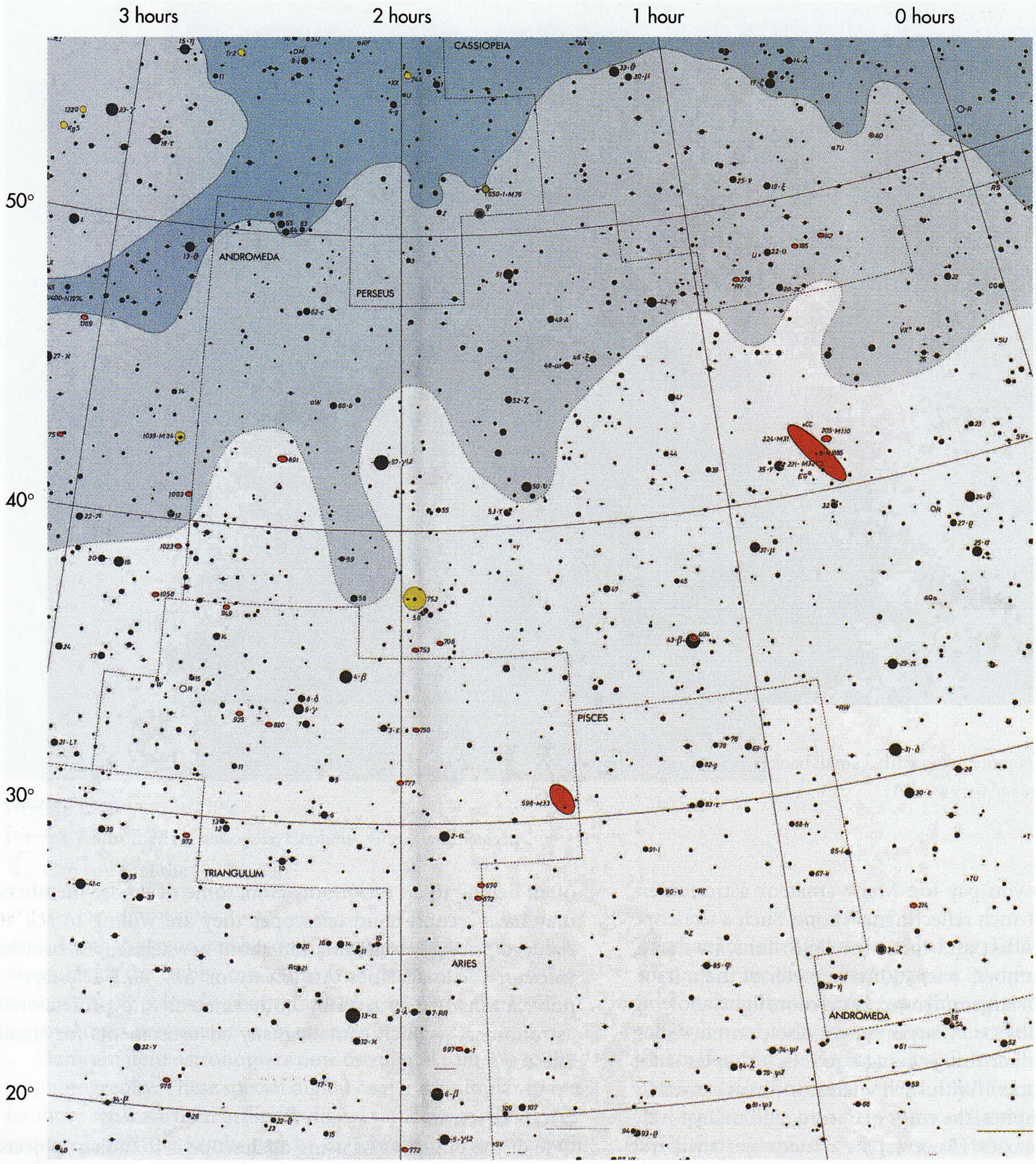

FIGURE E1.7
A modern star chart showing stars, galaxies, and coordinates.
(From Tirion, Wil. *Sky Atlas 2000.0.* Cambridge, Mass.: Sky Publishing Corp., 1981.)

Celestial Coordinates

The coordinate grid used by astronomers is similar to that used by navigators. The grid consists of one set of lines running east-west on the celestial sphere, parallel to the celestial equator, and another set running north-south, connecting one celestial pole to the other. The east-west lines play the same role as latitude on the Earth, but to avoid confusion with terrestrial coordinates, they are called lines of **declination,** or "dec" for short. The north-south lines play the same role as longitude on the Earth and are called lines of **right ascension,** or "RA" for short. Declination values run from +90° to −90° (the north and south celestial poles), with 0° being the celestial equator. Right-ascension lines divide the celestial sphere into 24 equal zones that are labeled not in degrees but in units of time. Thus, the right ascension of an object is given in hours (h), minutes (m), and seconds (s). Because the 360° around the sky is divided into 24 segments, each hour of RA equals 15°; that is, 360° divided by 24 = 15°. The point $0^h\,0^m\,0^s$ of RA is arbitrarily chosen to be

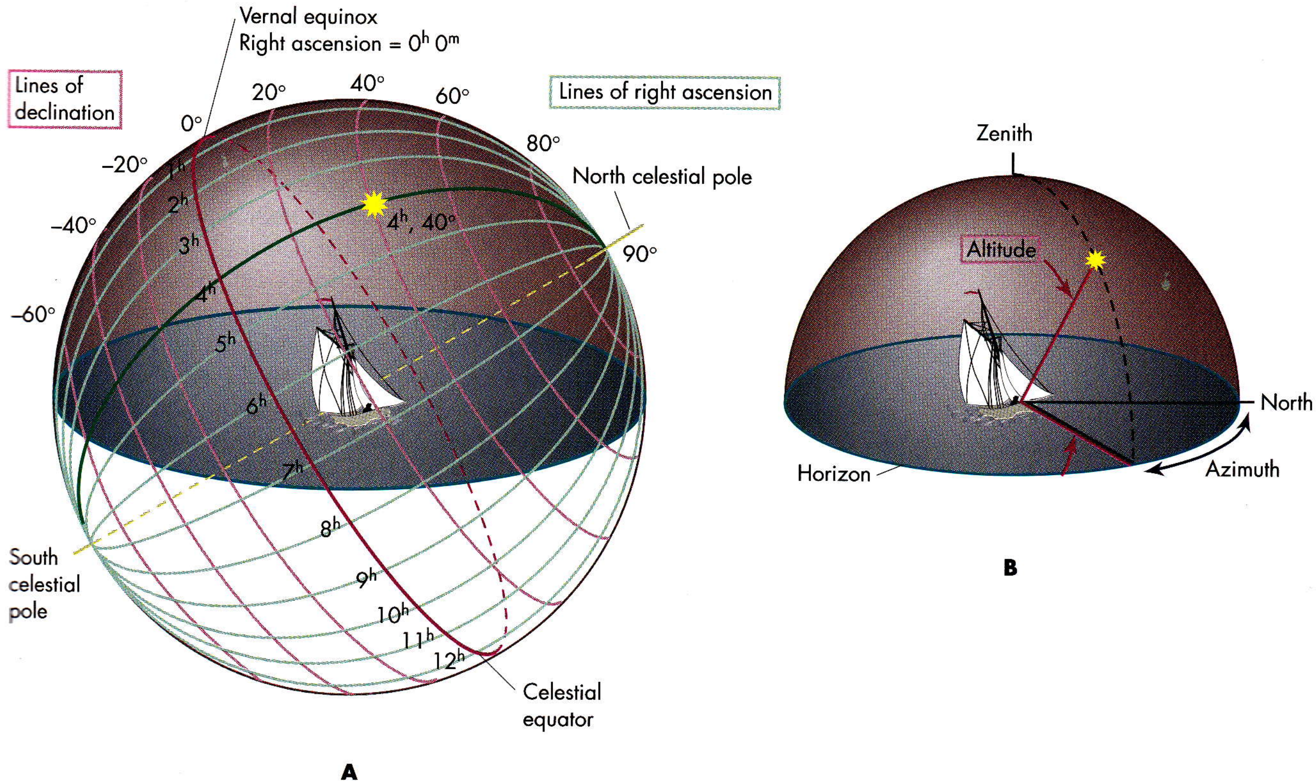

FIGURE E1.8
(A) Locating a star according to right ascension and declination. (B) Locating a star according to altitude and azimuth.

where the Sun's path, the ecliptic, crosses the celestial equator as the Sun moves north (fig. E1.8A).

Right ascension and declination are not the only way to locate objects on the sky. For example, a celestial object may be located by its altitude and azimuth, as illustrated in figure E1.8B. In this so-called horizon system, **altitude** is an object's angle above the horizon. **Azimuth** is generally defined as the angle measured eastward along the horizon from North to the point directly below the object, although sometimes it is measured from South. Whichever convention is used for azimuth, these coordinates are useful for pointing out objects or tracking their motion. However, they have a serious drawback compared to the otherwise seemingly cumbersome right ascension and declination: an astronomical body's altitude and azimuth constantly change as it moves across the sky, whereas, because they are defined with respect to the rotating celestial sphere, a body's right ascension and declination remain the same as a body rises and sets.

With a set of coordinate lines established, we can now locate astronomical objects on the sky the same way we can locate places on the Earth. For example, M31, a galaxy in the Local Group, is at right ascension 0 hours 42.7 minutes (0^h 42.7^m) declination $+41°16'$, as you can see in figure E1.7.

Planetary Configurations

Because planets move across the stellar background, astronomers have invented some terms to help describe where they are located at any given time. These terms describe a planet's position with respect to the Earth and the Sun—planetary configurations—and are shown in figure E1.9. Understanding these terms when they are used can help you find planets.

If a planet lies in the sky in the same direction as the Sun, it is said to be at **conjunction.** If it lies approximately between us

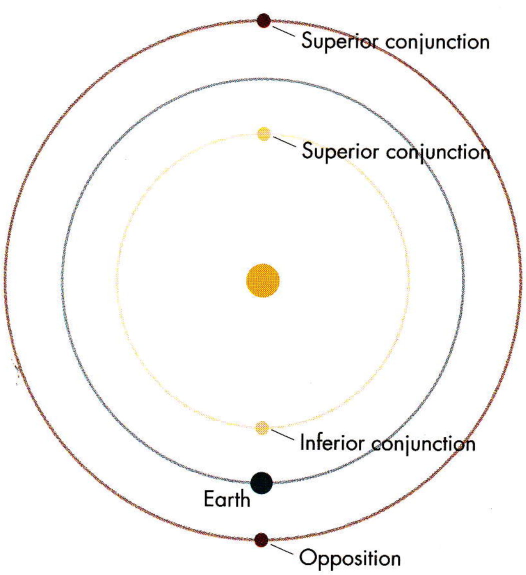

FIGURE E1.9
Planetary configurations: opposition, superior conjunction, and inferior conjunction.

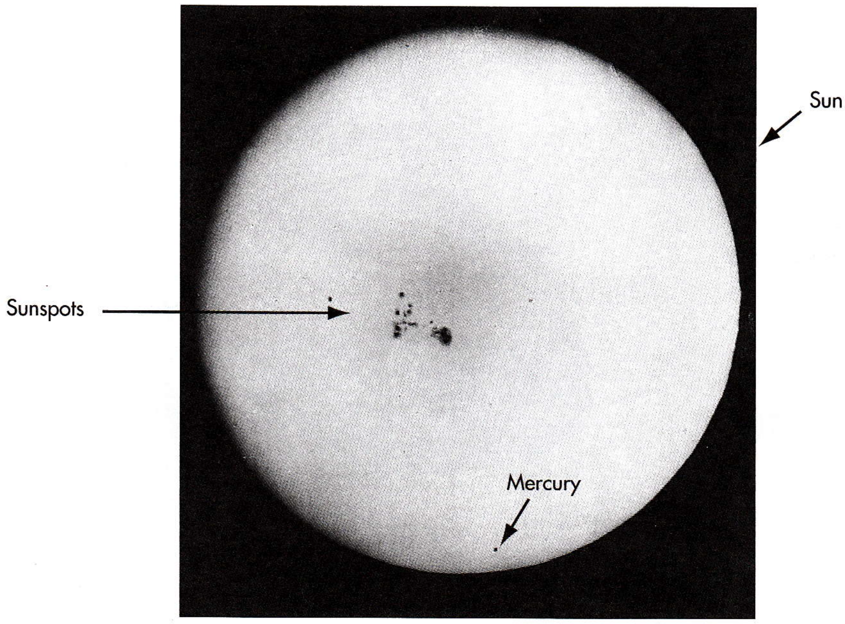

FIGURE E1.10

Transit of Mercury, November 14, 1907, photographed at the Yerkes Observatory of the University of Chicago. Upcoming transits will occur on the following dates: May 7, 2003; Nov. 8, 2006; and May 9, 2016.
(Courtesy of Yerkes Observatory.)

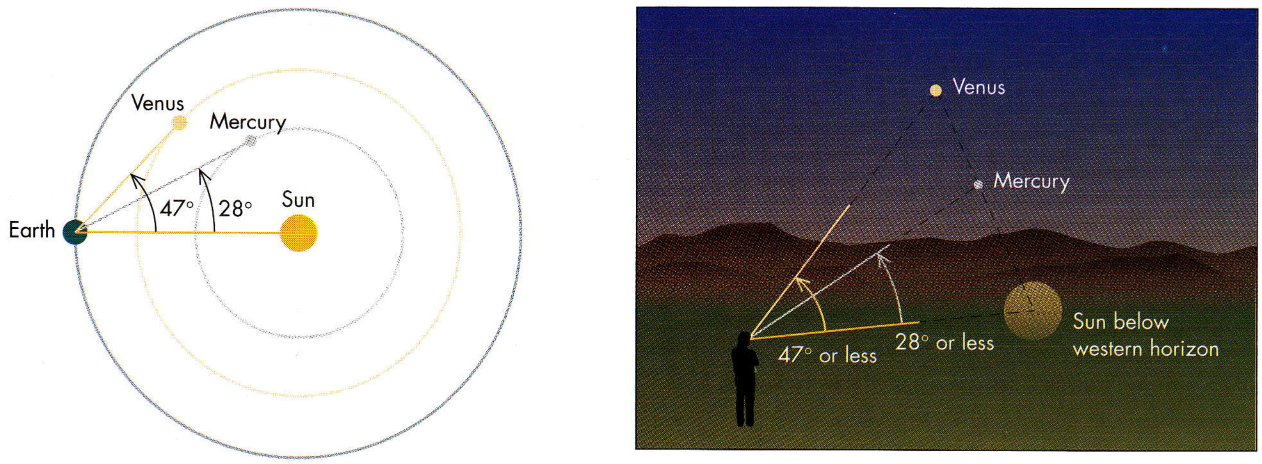

FIGURE E1.11

Elongations of Mercury and Venus and the Evening star phenomenon.

and the Sun, it is at **inferior conjunction.** If it is on the other side of the Sun, it is at **superior conjunction.**

Planets are very hard to see at either conjunction because they are hidden in the Sun's glare. On some very rare occasions, a planet may pass directly between us and the Sun. We may then see it silhouetted against the Sun's bright disk, as shown in figure E1.10. Such an event is called a **transit.** Only Mercury and Venus can transit the Sun as seen from Earth, but we can imagine talking with an astronaut on Mars who has just witnessed the Earth transiting the Sun. This would occur when Mars is directly opposite the Sun in the sky, or at what seen from Earth is called **opposition.**

When an outer planet is at opposition, it is nearest Earth, as well as being brightest and easiest to see, rising at sunset. Inner planets, too, are easiest to see when they appear farthest away from the Sun. However, as shown in figure E1.11, they can never get very far from the Sun. For example, Mercury can

Mercury and Venus as the morning star and the evening star

never be more than 28° from the Sun and Venus never more than 47° as seen on the sky. It is for this reason that Mercury and Venus are usually visible only in the morning or evening sky when the Sun is just below the horizon.

A planet seen close to the Sun at dawn or dusk is sometimes called the **Morning** or **Evening star.** When a planet is at its greatest angular separation from the Sun, it is said to be at **greatest elongation**—which can be either western or eastern.

The time interval between successive planetary configurations of the same type is called the **synodic period.** The synodic period differs from the planet's orbital period because both the Earth and the other planets move around the Sun. Thus, the interval between oppositions is neither an Earth year nor another planet's orbital period. For example, the Earth takes about 2 years to catch up to and overtake Mars after an opposition. The Earth overtakes the slower moving, more distant planets more quickly, and the interval between oppositions is close to a year. Thus, the Martian synodic period is about 780 days, whereas the Saturnian synodic period is 378 days.

Your Eyes at Night

You will soon discover that the longer you stay outside in dim light, the more sensitive your eyes will become and the fainter the stars you will be able to see. This is the result of physiological changes in your eye referred to as **dark adaption.**

The simplest change in your eye occurring in dim light is that the pupil opens wider. This is easy to verify by looking at yourself in a mirror in a dimly lit room. In full sunlight, your pupil normally has a diameter of about 2 millimeters, but in total darkness, its diameter may expand to about 7 or 8 millimeters, thereby allowing more light to enter your eye. The same principle is used in cameras when you adjust the aperture to match the available light.

Your eyes undergo another change in the dark. Chemical changes make the dark-adapted retina about 1 million times more sensitive to light than that under full daylight conditions. The process takes about 20 minutes to get well established but is undone by even a few seconds' exposure to bright light. Thus, once you are dark-adapted, you should stay away from bright lights for as long as you intend to observe.

In addition to becoming more sensitive to light, your eye also changes its sensitivity to color slightly, a phenomenon known as the "Purkinje effect." In full daylight, the eye responds best to greenish colors. At low light levels, it responds best to slightly bluer colors. This is probably the result of natural selection because starlight is much bluer than sunlight and eyes responsive to blue will therefore aid survival. It is certainly the case that night-flying insects see blue light better than yellow. That is the reason bug-zappers use a blue light to attract insects and why a yellow light bulb is often used for outdoor night lighting to be less attractive to insects.

You may also notice that it is easier to see very faint objects if you don't look directly at them but instead look a little to one side. The greater sensitivity you enjoy from this so-called **averted vision** arises because the center of your field of view is densely packed with receptors designed to allow you to see fine details. These receptors are better at showing fine structure than at seeing faint light. Thus, looking slightly to one side of a faint object makes it easier to see.

Summary

Looking at the night sky is not only fun, it will help you understand some of the phenomena described in chapter 1. Star maps will help you identify constellations and bright stars, and by learning the mythology of the stars, you will be able to find your way around the night sky more easily. In addition, you will forge a link to distant and ancient cultures. For many people, backyard astronomy—even with simple equipment—is an enjoyable and exciting hobby. Perhaps you will discover a comet and have it named for you!

Questions for Review

1. Approximately where would you look for Mercury in the sky about sunset?
2. What is meant by "Morning star"?
3. If a planet is at opposition and you see it high in the sky, about what time of night must it be?
4. Can you see Mercury in the western sky at dawn?
5. What is meant by "dark adaption"?
6. Why does the pupil of your eye get bigger in dim light?
7. What is averted vision?
8. What is right ascension?
9. What is declination?
10. What is azimuth?

Test Yourself

1. As a star rises and moves across the sky, which of the following change?
   (a) Its right ascension
   (b) Its declination
   (c) Its azimuth
   (d) Both (a) and (b)
   (e) None of the above
2. A planet is at inferior conjunction. It therefore rises at approximately
   (a) sunset.
   (b) sunrise.
   (c) midnight.
   (d) 2 hours before the Sun.
   (e) You can't tell from the available information.
3. If Mercury is at greatest elongation to the west of the Sun, it will be easiest to see
   (a) just before dawn.
   (b) just after sunset.
   (c) about midnight.
   (d) just before sunset.
   (e) None of the above

4. Which of the following planets can be at inferior conjunction?
   (a) Jupiter
   (b) Mars
   (c) Uranus
   (d) Venus
   (e) All of them
5. When your eye is dark-adapted
   (a) your pupils are smallest.
   (b) your pupils are biggest.
   (c) your color vision is at its most sensitive.
   (d) your eye is most sensitive to light.
   (e) Both (b) and (d)

Further Explorations

Allen, Richard Hinckley. *Star Names: Their Lore and Meaning.* New York: Dover, 1963.

Aveni, Anthony. *Conversing with the Planets.* New York: Times Books, 1992.

Berman, Bob. *Secrets of the Night Sky: The Most Amazing Things in the Universe You Can See with the Naked Eye.* New York: W. Morrow, 1995.

Covington, Michael. *Astrophotography for the Amateur.* New York: Cambridge University Press, 1985.

Hamilton, Edith. *Mythology.* New York: (Mentor) NAL-Dutton. 1953.

Harrington, P. "South for the Winter." *Sky and Telescope* 83 (February 1992): 142.

Levy, David H. *The Quest for Comets: An Explosive Trail of Beauty and Danger.* New York: Plenum Press, 1994.

Mechler, Gary. *Galaxies and Other Deep-Sky Objects.* New York: Knopf, 1995. (One in a series of National Audubon Society Pocket Guides.)

Muirden, James, ed. *Sky Watcher's Handbook: The Expert Reference Source for the Amateur Astronomer.* New York: W. H. Freeman, 1993.

Nagler, A. "Choosing Your Telescope's Magnification." *Sky and Telescope* 81 (May 1991): 553.

Newton, Jack. *Guide to Amateur Astronomy.* Cambridge, England: Cambridge University Press, 1995.

Observer's Handbook. Toronto: Royal Astronomical Society of Canada.

Pasachoff, Jay, and Donald H. Menzel. *Field Guide to the Stars and Planets,* 2d ed. Boston: Houghton Mifflin, 1992.

Ridpath, Ian. "The Origin of Our Constellations." *Mercury* 19 (November/December 1990): 163.

Schaaf, Fred. *Wonders of the Sky: Observing Rainbows, Comets, Eclipses, the Stars, and Other Phenomena.* New York: Dover, 1983.

Sesti, Giuseppe M. *The Glorious Constellations: History and Mythology.* New York: Harry N. Abrams, 1991. *This beautiful book contains extensive descriptions of the constellations and their mythology from many ancient cultures.*

Staal, Julius D. W. *The New Patterns in the Sky: Myths and Legends of the Stars.* Blacksburg, Va.: McDonald and Woodward, 1988.

Strom, Karen D. "Photographing the Stars." *Physics Teacher* 34 (September 1996): 340.

Tirion, Wil. *The Cambridge Star Atlas,* 2d ed. New York: Cambridge University Press, 1996.

Two excellent magazines for the amateur astronomer are the following:

Astronomy, published by Kalmbach Publishing Co., 21027 Crossroads Circle, P.O. Box 1612, Waukesha, WI 53187.

Sky and Telescope, published by Sky Publishing Corporation, P.O. Box 9111, Belmont, MA 02178-9111.

Web Site

"Backyard Astronomy: Tips on observing the Universe," by *Sky and Telescope:* **http://skyandtelescope.com/howto/scopes/article_241_1.asp**

An excellent site with many useful links and good advice about choosing telescopes.

Key Terms

altitude, 67
asterism, 62
averted vision, 69
azimuth, 67
conjunction, 67
dark adaption, 69
declination, 66
greatest elongation, 69
inferior conjunction, 68
Morning/Evening star, 69
opposition, 68
right ascension, 66
superior conjunction, 68
synodic period, 69
transit, 68